

# Correlations between Transversus Abdominis Thickness, Lumbar Stability, and Balance of Female University Students

WONTAE GONG, PhD, PT<sup>1)</sup>

<sup>1)</sup> Department of Physical Therapy, Korea Nazarene University: Wolbong Ro 48, Seobuk-gu, Cheonan-si, Chungcheongnam-do 330-718, Republic of Korea. TEL: +82 41-570-4286, FAX: +82 41-570-7925

**Abstract.** [Purpose] The purpose of the present study was to analyze the correlations of the thicknesses of the transversus abdominis muscle (Tra) and the internal obliquus abdominis muscle (Io) with static lumbar stability (SLS), dynamic lumbar stability (DLS), and balance. [Subjects] The subjects of the present study were 40 female university students who had no physical defects or pain. [Methods] The thicknesses of Tra and Io muscles were measured using an ultrasonic imaging diagnostic unit. SLS and DLS were measured using a Pressure Biofeedback Unit (PBU), and Weight Distribution Indexes (WDI) and stability scores (SS) were measured using a balance measuring unit. [Results] As the thickness of the Tra increased, SLS, DLS, WDI, and SS improved. As SLS improved, DLS and WDI were also improved. [Conclusion] To improve lumbar stability and balance, training is needed in order to increase the muscle mass of the transversus abdominis muscle.

**Key words:** Transversus abdominis, Lumbar stability, Balance

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## INTRODUCTION

Many studies have been conducted on spinal stabilization. The importance of spinal stabilization has been coming to the fore. However, because the structure of the spine is more unstable than those of other bones, the roles of the deep muscles are particularly important for spinal stabilization<sup>1)</sup>. Representative deep muscles of lumbar stabilization include the transversus abdominis muscle (Tra) and the multifidus muscle<sup>2)</sup>. The fact that Tra greatly contributes to lumbar stabilization has been proven by many studies, and the importance of this muscle has been established<sup>3)</sup>. In particular, through EMG measurement, Hodges and Richardson proved that Tra contracts before any limb movement<sup>4)</sup>.

Diverse studies have been conducted investigating the functions and thickness of Tra affecting lumbar stabilization and balance. It has been shown that the thickness of Tra increases with lumbar stabilization exercises<sup>5)</sup>, and some studies have indicated that dynamic balance can also be improved by lumbar stabilization exercises<sup>6)</sup>. Tra has been studied using ultrasonic imaging to measure changes in the thickness of Tra after Pilates exercises, methods have been used to activate Tra<sup>7)</sup>. It has been demonstrated that subjects with low back pain have weaker Tra contractile force using ultrasonic imaging<sup>8)</sup>, and changes in the thickness of Tra in various sitting positions have also been measured using ultrasonic imaging<sup>9)</sup>.

Some previous studies have examined the effects of the maximum contractile force of the transverse abdominis

muscle on the sacral angle, lumbar lordosis, lumbar ROM, and dynamic lumbar stability<sup>10)</sup>. These studies compared the contractile force of the transverse abdominis muscle with dynamic lumbar stability using a pressure biofeedback unit (PBU). However the effects of the thicknesses of Tra and Io on static and dynamic lumbar stability and balance have been insufficiently studied. Accordingly, the present study analyzed the correlations of the thicknesses of Tra and Io with static and dynamic lumbar stability and balance, to provide basic data for use in interventions for the improvement of lumbar stability and balance in clinics.

## SUBJECTS AND METHODS

The subjects of the present study were 40 female students in the department of physical therapy of N University in Chungcheong-do, Korea. The subjects' age (mean  $\pm$  SD) was  $20.9 \pm 0.9$  years, their height was  $161.7 \pm 5.2$  cm, and their weight was  $54.5 \pm 7.2$  kg. Those who had pain in the abdomen, those who were short of breath, and those who had difficulties with balance due to musculoskeletal problems were excluded. All the subjects who participated in the present study voluntarily agreed to participate after being sufficiently acquainted with the purpose of the study and the experiment.

The thicknesses of Tra and the Io were measured using an ultrasonic imaging diagnostic unit (Mysono U5, Samsung Medison, Korea). The ultrasonograph was set to B-mode, and 12 MHz linear probes were used. The subjects relaxed with their abdomens in a comfortable supine position. The measurer placed the probe transversely on the top

of the iliac crest, moved it toward the exact center of the abdomen in order to stop the screen at a position where all of the external oblique abdominal muscle, the internal oblique abdominal muscle, and Tra were visible, and measured the thicknesses of the internal oblique abdominal muscle and Tra at a point 13 mm distal from the point at which the fascia of the internal oblique abdominal muscle and the fascia of Tra met (Fig. 1). The measurement was done by a measurer who had received instruction in the use of the ultrasonic imaging unit and could use the unit proficiently.

To assess Static Lumbar Stability (SLS), the contractile force of Tra was assessed using a PBU (Chattanooga Group, Australia). A PBU is a simple device consisting of an inflatable non-elastic bag connected to a pressure gauge that is used to record and monitor pressure changes during the movement of the lumbar spinal/pelvic regions. The bag is 16.7×24.0 cm in size and can measure pressures from 0 to 200 mmHg. Excessive pressure changes during the assessment indicate that the movements in the lumbar spinal/pelvic regions are not controlled. To measure SLS, when subjects were in a prone position on a hard floor, the PBU was placed at the point at which the two anterior superior iliac spines cross each other below the navel. The measurement began with a baseline pressure of 70 mmHg. The subjects pulled in their lower abdomens maximally, without moving the waist or the hip, in order to reduce the pressure. When a constant pressure had been maintained for 10 seconds, the pressure of change was recorded<sup>11</sup>. To measure Dynamic Lumbar Stability (DLS), the subject performed the Bent Knee Fall Out (BKFO), as described by Comerford and Mottram<sup>12</sup>. The BKFO was performed by placing the PBU vertically 2 cm below the posterior superior iliac spines in the supine position, and to minimize trunk sway during movements, folded towels of the same height were placed on both sides of the PBU. The measurement began

with a baseline pressure of 40 mmHg, and the pressure of change was recorded during abduction of the hip joint in a posture in which the hip and knee of one leg were bent and the foot was in contact with the floor, then returned to the original posture.

A balance-measuring instrument (TetraX, BeamMed Ltd, Israel) was used to measure balance ability. This equipment consists of four force plates: two 12 cm wide, 19 cm long rectangular forefoot force plates, and two 12 cm wide, 12 cm long square rear foot force plates. Information on the pressure applied to the force plates when the subject was standing on the force plates was amplified, filtered, input to a computer, and analyzed using the TetraX software program. Balance was assessed in a quiet room. The subjects stood on both feet, without wearing shoes, in a comfortable posture. The measurement was performed for 32 seconds. Stability Scores (SS) are an indicator of the stability of the center of gravity. They measure the patterns of changes in the pressure applied to the individual force plates, and larger values mean larger variations in the center of gravity. The Weight Distribution Index (WDI) shows the percentiles of the weight placed on the four force plates, and the ideal is when 25% of the weight is placed on one force plate. When deviations from the ideal 25% are small, the WDI value is close to 0, and when deviations are large, the WDI value increases.

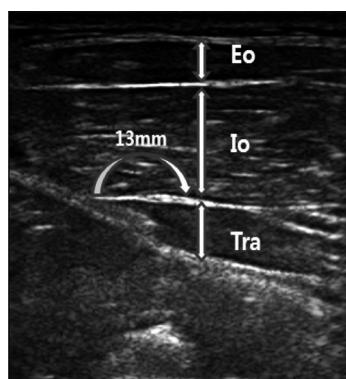
The measured data were analyzed using the SPSS 12.0 KO (SPSS, Chicago, IL, USA) statistical program. The recorded data are presented as mean  $\pm$  SD. To observe the correlations among Tra, Io, SLS, DLS, WDI, and SS, Pearson correlation coefficients were calculated. The statistical significance level was chosen as 0.05.

## RESULTS

The means  $\pm$  SD of Tra, Io, SLS, DLS, WDI, and SS are presented in Table 1. Regarding the correlations among Tra, Io, SLS, DLS, WDI, and SS, Tra and SLS showed a weak positive correlation in which SLS increased as Tra increased ( $r=0.25$ ), DLS showed a negative correlation with Tra in which DLS decreased as Tra increased ( $r=-0.34$ ), WDI showed a weak negative correlation ( $r=-0.27$ ), and SS showed a strong negative correlation ( $r=-0.43$ ). SLS and DLS ( $r=-0.36$ ) / WDI ( $r=-0.32$ ) showed negative correlations in which DLS and WDI decreased as SLS increased (Table 2).

## DISCUSSION

Previous studies have indicated that stabilization exercises strengthen Tra, and that stabilization exercises improve balance. In a study by Endleman and Critchley, 26 subjects



**Fig. 1.** Measurement of abdominal muscle thickness

**Table 1.** Mean $\pm$ SD (Unit-Tra, Io: mm, SLS, DLS: mmHg, WDI, SS: score)

Tra	Io	SLS	DLS	WDI	SS
0.29 $\pm$ 0.13	0.54 $\pm$ 0.11	2.71 $\pm$ 2.08	2.02 $\pm$ 1.18	5.42 $\pm$ 2.47	13.50 $\pm$ 4.74

Tra: transversus abdominis, Io: internal obliquus abdominis, SLS: static lumbar stability, DLS: dynamic lumbar stability, WDI: weight distribution index, SS: stability score

**Table 2.** Correlation of the Tra, Io, SLS, DLS, WDI, ST

Category	Tra	Io	SLS	DLS	WDI	SS
Tra	1					
Io	0.11	1				
SLS	0.25	-0.30	1			
DLS	-0.34*	0.21	-0.36*	1		
WDI	-0.27	0.11	-0.32*	0.13	1	
SS	-0.43**	-0.04	-0.21	0.14	0.17	1

\*\*p&lt;0.01, \*p&lt;0.05

Abbreviations are the same as in the Table 1.

performed Pilates exercises, which increased the thicknesses of Tra and the Io muscles<sup>7</sup>). Hides et al. measured that the thicknesses of the Tra and the Io muscles while subjects with lower back pain (n=20) and subjects without lower back pain (n=20) were performing a weight-bearing task, and their results indicate that the subjects with lower back pain manifested thin Tra contractions<sup>8</sup>. Ainscough-Potts et al. studied changes in the thickness of Tra in diverse sitting positions using ultrasonography, and reported that, the thickness of the Tra increased more when subjects were sitting on a chair or gym ball with one foot lifted from the ground than when both feet were placed on the ground<sup>9</sup>.

In a study by Kim et al., subjects dynamic balance improved after performing a lumbar stabilization exercise program<sup>13</sup>, and Carpes et al. reported that after applying a trunk strength and stability program for subjects with lower back pain, lower back pain was relieved, and body balance was improved<sup>6</sup>. Pinto et al. reported that neutral lumbar postures can facilitate an increase in the thickness of the Tra muscle while performing a leg task<sup>14</sup>.

Previous studies, as noted above, reported that stabilization exercises increase the thickness of the Tra and improve balance. However, there has been no previous study of correlations among transversus abdominis thickness, lumbar stability, and balance. Although many researchers have stressed the importance of the transversus abdominis in lumbar stabilization and reported that stability and balance improved through exercise strengthening this muscle, there is no research in the literature on how the thicknesses of the abdominal muscles affect lumbar stability and balance. Therefore, this study examined the correlations among transversus abdominis muscle thickness, lumbar stability, and balance. The results of the present study indicate that as the thickness of the Tra increased, SLS, DLS, WDI, and SS improved. The results also show that as SLS improved, DLS and WDI also improved. These results are similar to the results of studies reporting increases in the thickness of the Tra and improvement in balance in groups that performed a trunk strength and stability program or Pilates exercises.

Taken together, we consider that training to increase the

muscle mass of the transversus abdominis muscle is necessary to improve lumbar stability and balance. We hope that the results of the present study will be utilized as basic data in the treatment of patients in clinics.

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